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Technical Report 32-1413

*An Extensive English Language Bibliography
on Graph Theory and Its Applications*

Narsingh Deo

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**JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA**

October 15, 1969

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Preface

The work described in this report was performed under the cognizance of the Guidance and Control Division of the Jet Propulsion Laboratory.

The author delivered a series of 16 lectures on Graph Theory and Its Application at Jet Propulsion Laboratory's Applied Mathematics Seminar during Jan.-Mar., 1968. Since that time he has received numerous requests—from his colleagues at JPL, from students and faculty at Cal Tech, and from outside—for bibliographies in theory and applications of graphs. This technical report is compiled chiefly to meet this need.

As far as the author knows, the most extensive existing bibliography on the theory of linear graphs was compiled by A. A. Zykov in early 1963 for the symposium held at Smolenice, Czechoslovakia in June 1963. This bibliography was an extension of an earlier bibliography by J. W. Moon and L. Moser.

Although Zykov's bibliography has served as an excellent source of information for research workers and students, it has its shortcomings. It is 6 years old and hence is in obvious need of updating. Moreover, it left out many significant references which were more concerned with the applications of graphs than their theory. In other words, Zykov's bibliography was more for mathematicians than for engineers. Also his bibliography contains numerous errors on dates, names, volume numbers, etc.

In this bibliography, the author has tried to take into account these factors. For the sake of space, only those sources which are in English—original or in translation—have been listed. Unpublished works, private communications, and technical reports not generally available have been omitted. Internal reports, subsequently published in open literature, also have been left out. Names of authors have been arranged alphabetically, with their works first in chronological order and then in alphabetical order within the chronological order. Co-authors and their works directly follow the first author alphabetically as originally listed in the work. With this system, the reader may check for works co-authored by certain writers by quickly checking the second, third, or fourth author name throughout the alphabet.

It is hoped that this bibliography will be of service to students of graph theory—both applied and pure. Abbreviations for Journals are those used by *Mathematical Review*.

Acknowledgment

The author is grateful to many persons for their help in the arduous task of preparing this bibliography. Kay Haines of the JPL Library and her staff assisted in literature search. Eleanor Griggs, June Giffin and other secretaries in the Guidance and Control Division did most of the original typing. Dave Rubin, John Wedel and Bill Scott provided valuable encouragement and suggestions. Lee Godfrey of the Publications Section has made an invaluable contribution in the editing of this report. But most of all, I am indebted to my wife Karen for assistance in this work. She sat home evening after evening reading, typing, clipping, sorting, pasting, and retyping thousands of the references from which this bibliography was culled.

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Abstract

This report contains an up-to-date and complete English language bibliography in Linear Graph Theory (or network theory) and its applications. It has about 2200 entries, which include almost all significant works published on the subject in the English language—original or translated—prior to April 1969. Only one-third of these 2200 entries had been included in Zykov's bibliography. Unpublished works, private communications, and internal company-reports, not generally available, have been omitted.

This report, which has a brief introduction to the theory and applications of graphs, is a guide, for the beginner, to reading material in the field. It also contains short reviews of 18 books—eight of which are text books on graph theory.

The report has been written for a serious, English-speaking, student or research-worker interested in the theory and applications of graphs.

An Extensive English Language Bibliography on Graph Theory and Its Applications

Introduction

Linear Graph Theory (or Graph Theory) may be considered an extended and special branch of combinatorial topology.¹ A graph² consists of a set of points³, and a set of lines⁴ connecting these points. It is immaterial whether these lines are long or short, straight or crooked. What is important, however, is the incidence relationship between these lines and points. A study of the properties of graphs is graph theory. Graphs come in many varieties: connected or disconnected, directed or undirected, weighted or unweighted, planar or nonplanar, finite or infinite, just to name a few.

Applications of Graph Theory

It is this simplicity which makes graph theory one of the most elegant and useful branches of mathematics. A graph can be used to represent almost any physical situation involving discrete objects and a relationship among them. Graph theory has been applied to fantastically diverse fields—from macromolecule chemistry to dynamic programming, from game theory to flow of oil through a network of pipes, from communication theory to sociological problems, from traffic network to statistical physics, from layout design of monolithic large-scale-integrated circuits to information storage and retrieval.

¹Extended because in combinatorial topology there is no provision for directed graphs.

²A graph is also called a linear graph, a linear complex, a 1-complex, or a 1-dimensional complex.

³A point is also called a node, a vertex, or an 0-simplex.

⁴A line is also called an edge, an arc, a branch, a 1-simplex, or an element.

As an example, let us consider the application of graphs in computer science. Graphs can be used in logic design, in designing reliable codes, in studying the reliable layout for the different subsystems of the machine, and in avoiding errors due to races in an automaton. Graphs can be used in actual hardware design such as large-scale-integrated digital circuits. They can be used in arriving at an optimal back-plane wiring. Furthermore, graphs can be used in designing the programming language, in compilation, and in studying flowcharts. Graphs are an immense aid to the study of syntactical structure of a computer language. Trees and rooted trees are used in information processing. Many algorithms for sorting are based on properties of certain graphs. Graphs can be used in designing programs for a time-shared machine. Finally, graph theory can be applied in developing self-testing or self-diagnosable machines.

Thus a student of computer science, for instance, stands to gain a great deal if he becomes familiar with elements of graph theory.

Where to Begin

One who is totally unfamiliar with graph theory should start with *Graphs and Their Uses* by Oystein Ore. This 131-page paperback is an elementary easy-to-read book. A surprisingly large number of important topics are introduced in this short book. It requires little mathematical background.

Text Books on Graph Theory

Having read *Graphs and Their Uses*, one can proceed to more detailed treatment of the subject given in one or more of the following text books:

- (1) Berge, C., *The Theory of Graphs and Its Applications*. John Wiley & Sons, Inc., New York, 1962. 247 pages. The English translation of the original book in French is *Théorie des graphes et ses applications*. Dunod, Paris, 1958.

This was the second book ever written on graph theory. (The first one was D. König's, *Theorie der endlichen und unendlichen Graphen*, Leipzig, 1936. This classical work yet remains to be translated into English.) Hence, it is perhaps the best known book on graph theory. Every graph theorist has read it at least once.

Although it is an excellent book and worth reading, it is not the easiest book to read on the subject. It is written more for the students of mathematics than for those of engineering, although it contains numerous examples of applications to problems of game theory, switching circuits, transport networks, and sociology.

A novice would find it hard to read. This book should be read after one has read (2), (5), or (8) following.

- (2) Busacker, R. B., and Saaty, T. L., *Finite Graphs and Networks: An Introduction with Applications*. McGraw-Hill Book Co., Inc., New York, 1965. 294 pages.

This is an excellent introductory book on the subject. It is well-written and can be read independently without the aid of a course or teacher. It is written specially for those who are interested in immediate application of graph theory to engineering problems. A mathematician familiar with the subject may find it somewhat repetitious, diffuse, lacking rigor, and perhaps not abstract enough.

In the words of the authors: "A knowledge of basic concepts in set theory and a brief familiarity with vectors and matrices is all that is necessary for an understanding of this material."

The first half of the book deals with the theory and second half with interesting and useful applications.

The authors have made generous use of figures to illustrate the subject matter. There is an excellent index and a useful glossary.

- (3) Harary, F., Norman, R. Z., and Cartwright, D., *Structural Models: An Introduction to the Theory of Directed Graphs*. John Wiley & Sons, Inc., New York, 1965. 415 pages.

As the title states, this is not a text book on general theory of graphs. It deals only with directed graphs. Although it is a well-written book and requires little mathematical background, it is not a book for a beginner in graph theory. One should first read (2) or (5) and then read this one.

It is a definitive book on the subject, written by two mathematicians and a psychologist. This book, with one exception, contains few examples of engineering applications; the last chapter, however, contains a 25-page good introduction to transportation theory. There is a very useful glossary at the end of the book.

- (4) Kim, W. H., and Chien, R. T., *Topological Analysis and Synthesis of Communication Networks*. Columbia University Press, New York, 1962. 307 pages.

Although written principally for electrical engineers, the text contains a good introduction to the theory. Although an electrical engineer will find this delightful reading, it is not recommended for non-electrical engineers who may have difficulty in reading it. This book deals chiefly, and in full detail, with the topological aspects of N -port networks, contract networks, signal flow graphs, and communication nets.

- (5) Ore, O., *Graphs and Their Uses*. Random House, New York, 1963. 131 pages.

This paperback on graph theory is written for the high school student, and therefore requires no mathematical background. Yet the author manages to introduce to the reader a surprisingly large number of important areas of graph theory, such as Euler's graphs, trees, matching, directed graphs, planar and dual graphs, the four-color problem, the Platonic bodies, and mosaics.

This is a well-written book, generously illustrated with figures, and is extremely interesting. Anyone new to the field of graph theory will do well to begin with this one.

- (6) Ore, O., *Theory of Graphs*. American Mathematical Society, Providence, R. I., 1962. 270 pages.

This is a standard classroom text book on graph theory, written for mathematics majors. A newcomer will find it difficult to study without the aid of a teacher. The material covered is more complete than most books on graph theory, but the book does not contain as many examples of applications as (1), (2), (4) or (7). The text is somewhat bogged down by too many definitions.

It is an advanced book; one should attempt to read it only after having read more elementary ones, such as (2) and (5).

- (7) Seshu, S., and Reed, M. B., *Linear Graphs and Electrical Networks*. Addison-Wesley Publishing Co., Inc., Reading, Mass., 1961. 315 pages.

This book is also primarily written for electrical engineers. But the first five chapters will serve as a lucid introduction to graph theory even for mathematicians. It is an extremely well-written book. It contains more graph theory than (4) or (5), but not as much as (1) or (6).

This is the most complete book on topological analysis and synthesis electrical networks. It also includes applications of graph theory to switching circuits and sequential machines. Many important topics of pure graph theory, which have no immediate applications to electrical networks, are left out. For examples, enumeration of graphs, four-color problems, chromatic graphs, and Euler's formula are not even mentioned.

- (8) Tutte, W. T., *Connectivity in Graphs*. University of Toronto Press, Toronto, Ont., Oxford University Press, London, 1966. 145 pages.

This small book presents only a segment of graph theory, but it does so in depth. The areas covered are connectivity, non-separability, triple connection, etc., in undirected graphs. The author intended it to be Volume I of a three-volume treatment of graph theory. It is not a complete text book on the subject, and is, therefore, not a book for the uninitiated; it is written specifically for advanced students and researchers in the field. The author uses many of his own terminologies instead of those widely accepted in the field.

Other Books on or Related to Graph Theory

Additional books on the subject of graph theory are:

- (1) *Applied Combinatorial Mathematics*. Edited by E. F. Beckenbach. John Wiley & Sons, Inc., New York, 1964. 608 pages.

This book contains two excellent chapters on graph theory: Chapter 6, "Combinational Problems in Graphical Enumeration," by F. Harary; and Chapter 12, "Network Flow Problems," by E. F. Beckenbach.

- (2) *Theory of Graphs: Proceedings of the Colloquium held at Tihany, Hungary, in September 1966*. Edited by P. Erdős and G. Katona. Academic Press, Inc., New York, 1968. 370 pages.

This is a collection of 34 independent research papers. It contains solutions of some problems posed in Smolenice in 1963, (3), below, and a set of new problems. This too is only for the advanced student and research worker.

- (3) *Theory of Graphs and Its Applications: Proceedings of the Symposium held in Smolenice, Czechoslovakia in June 1963*. Edited by M. Fiedler. Academic Press, Inc., New York, 1964. 234 pages.

This is not a text book on graph theory. It contains 12 lectures, nine papers, a set of problems and a good bibliography. This book is for advanced students and research workers in graph theory.

- (4) Ford, Jr., L. R., and Fulkerson, D. R., "*Flows in Networks*." Princeton University Press, Princeton, N.J., 1962. 194 pages.

This well-written book is mostly concerned with application of graph theory to operations-research and transportation problems, such as routing, scheduling, inventory control, etc. The book contains little for a pure graph theorist.

- (5) Harary, F., and Norman, R. Z., *Graph Theory as a Mathematical Model in Social Science*. University of Michigan, Ann Arbor, Michigan, 1953. 45 pages.

This little booklet was written for social scientists with no mathematical background. This well-written and extremely elementary book shows how linear graphs can be used in sociological studies.

- (6) *Graph Theory and Theoretical Physics: Proceedings of NATO Summer School held at Frascati, Italy, in 1964*. Edited by F. Harary. Academic Press, Inc., New York, 1967. 355 pages.

This is a collection of 12 research and survey papers in graph theory. About half of these are on applications of graphs to crystal physics, electrical networks, etc.; others are in pure graph theory, such as enumeration of graphs, perfect graphs, etc. This too is not a text book, but it does have some excellent survey-papers on some specific topics.

- (7) *A Seminar on Graph Theory*. Edited by F. Harary and L. Beineke. Holt, Rinehart & Winston, Inc., New York, 1967. 116 pages.

This monograph is a loosely connected set of 14 lectures given at a seminar during 1962–1963 at the University of London. The first six lectures are by Harary, the rest by other well-known graph theorists. This is an excellent book for an intermediate level study of graph theory. It is not a text book.

- (8) Liu, C. L., *Introduction to Combinatorial Mathematics*. McGraw-Hill Book Co., Inc., New York, 1968. 393 pages.

Although this is not a book on graph theory, it does contain some excellent introductory material on the subject. It has three well-written chapters on graphs: Chapter 6, "Fundamental Concepts in the Theory of Graphs," Chapter 7, "Trees, Circuits, and Cut-Sets," and Chapter 8, "Planar and Dual Graphs." These chapters are particularly recommended to those who are familiar with concepts of sets, relations, and groups. Subsequent chapters also deal with graph related topics, such as, transport networks, matching theory, and block designs.

This is a must for those interested in enumeration of graphs.

- (9) Moon, J. W., *Topics on Tournaments*, Holt, Rinehart & Winston, Inc., New York, 1968. 104 pages.

As the title states, this little book deals exclusively with the theory of tournaments. A tournament (or round-robin tournament) is a certain special type of directed graph, which is also used as a model for *paired comparisons*. This is a well-written book, but it requires some knowledge of set theory and graphs.

- (10) Riordan, J., *An Introduction to Combinatorial Analysis*, John Wiley & Sons, Inc., New York, 1958. 244 pages.

This is not a book on graph theory as such, but Chapter 6, "Partitions, Compositions, Trees, and Networks," pp. 107-162, is invaluable for a student interested in enumeration of graphs.

- (11) *Theory of Graphs: International Symposium, held in Rome, Italy, in July 1966*. Edited by P. Rosenstiehl. Gordon & Breach, Inc., New York; Dunod, Paris, 1967. 416 pages.

This also is not a text book. It contains 46 short, research and survey papers in English and 13 in French, mostly on pure aspects of graph theory, and a few also on applications of graphs to logical networks, statistical physics, languages, transportation problem, etc. This book is also for advanced students and research workers in the field.

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